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(54) Synergistic composition comprising a fibroblast growth factor and a sulfated polysaccharide, for use as antiviral agent.

(57) A pharmaceutical composition is provided for use in the prevention or treatment of viral infections caused by enveloped viruses. The composition comprises a fibroblast growth factor, a sulfated polysaccharide with antiviral activity, and one or more pharmaceutically acceptable carriers.

The fibroblast growth factor may be a basic fibroblast growth factor or an analogue thereof, and the polysaccharide may be a carrageenan, heparin, dextran sulfate, pentosan polysulfate or a sulfated polysaccharides produced by marine algae belonging to the class of Rhodophyceae.

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The present invention relates to a synergistic pharmaceutical composition having antiviral activity which comprises a fibroblast growth factor, a sulfated polysaccharide with antiviral activity and any acceptable pharmaceutical excipient or excipients, for the use in the prevention or treatment of viral infections caused by enveloped viruses.

Enveloped viruses are, for example, herpes virus type  $\alpha$ , e.g., herpes simplex virus (HSV); herpes virus type  $\beta$  or  $\gamma$ , e.g. cytomegalovirus; orthomyxovirus, e.g. influenza virus; paramyxovirus, e.g. human respiratory syncytial virus (HRSV); tropical viruses responsible for exanthematous fevers and/or encephalitis, e.g. Semliki Forest Virus (SFV), or other tropical diseases, belonging, e.g., to the "Toga" and "Arena", groups of viruses; or retrovirus, e.g. the HIV virus responsible for the acquired immuno deficiency syndrome and the MSV virus responsible for the Moloney Sarcoma virus.

A fibroblast growth factor according to the invention may be either a basic fibroblast growth factor or an acidic fibroblast growth factor, or their analogs.

A sulfated polysaccharide with antiviral activity according to the invention may be, e.g., one selected from the group consisting of a carragenan, e.g.  $\lambda$  carrageenan, heparin, dextran sulfate, pentosan polysulfate, mannane sulfate, dermatan sulfate, heparin super-sulfated, dermatan super-sulfated and agarose-type sulfated polysaccharides e.g. produced by marine algae belonging to the class of Rhodophyceae.

Although much effort has been made to fight the infections caused by the enveloped viruses no really effective drug has yet been identified.

FGF is known as a promoter of angiogenesis, wound healing, tissues regeneration, including bone and nerve tissues.

Kaner et al. (Science 248, 1410, 1990) demonstrated that the b-FGF receptor is a portal of cellular entry for HSV type 1. Inhibitors of b-FGF binding to its receptor and competitive antagonists of b-FGF prevent HSV-1 uptake.

We also showed that b-FGF prevents the growth and infectivity of other viruses like herpes simplex type 2 (HSV-2), respiratory syncytial virus (HRSV), Semliki forest virus (SFV), human immunodeficiency virus (HIV) and Moloney sarcoma virus (MSV) (our copending Italian patent application No. 22804A/89).

Sulfated polysaccharides are known to be potent and selective inhibitors of various enveloped virus (Antiviral Research 9, 335-343, 1988; ibidem, 233-246, 1989; ibidem, 12, 1-20, 1989; Antimicrobial Ag. and Chemioth. 31, 1524-1528, 1987; ibidem 31, 1388-1393, 1987; 32, 1742-1745, 1988; Science 240, 646-653, 1988; The Lancet, June 13, 1979-1982, 1987; Virology 164, 542-546, 1988).

We have surprisingly found that combining a fibroblast growth factor and a sulfated polysaccharide, the obtained antiviral activity is superior to that expected from the sum of the antiviral activities of the individual constituents of the combination, thus indicating the presence of a synergistic effect. The combination of the two components is therefore more effective in the treatment of the viral infections.

The present invention relates to a synergistic pharmaceutical composition having antiviral activity which comprises a fibroblast growth factor, a sulfated polysaccharide with antiviral activity and any acceptable pharmaceutical excipient or excipients, for use in the prevention or treatment of viral infections caused by enveloped viruses.

The invention further concerns a process for preparing the above mentioned composition, comprising the step of combining a fibroblast growth factor, and a sulfated polysaccharide in a pharmaceutically acceptable excipient or excipients.

In particular, the invention refers to the prevention and treatment, by use of a composition according to the invention of infections caused by alpha type herpes viruses such as, e.g., herpes simplex virus (HSV), in particular HSV-1 and HSV-2, and herpes varicella/zoster; beta or gamma type herpes viruses, e.g. cytomegalovirus; orthomyxovirus, e.g. influenza virus, paramyxovirus, e.g. human respiratory syncytial virus (HRSV); tropical viruses responsible for exanthematous fevers and/or encephalitis, e.g. Semliki Forest virus (SFV) or other tropical diseases, belonging, e.g., to the "Toga" and "Arena" groups of viruses; or retroviruses, e.g. the HIV virus responsible for the acquired immune deficiency syndrome and the MSV virus responsible for the Moloney Sarcoma virus.

Particular examples of viruses towards which the pharmaceutical composition according to the invention have proved to be effective are, e.g., the herpes simplex viruses (HSV), in particular HSV-1 and HSV-2.

A fibroblast growth factor (FGF) according to the invention can be either basic FGF (bFGF), human or bovine, or acidic FGF (aFGF), human or bovine, or an analogue of the aforesaid bFGF and aFGF.

The aforementioned growth factors, namely human and bovine bFGF and human or bovine aFGF, are known factors, which are described for example in the published international patent applications PCT WO86/07595 and PCT WO87/01728, and in the published European patent applications N° 226181, N° 237966 and N° 259953, as well as in various scientific articles such as for example, Science vol. 233, pp. 545-548, August 1st, 1986; Embo Journal Vol. 5, N° 10, pp.2523-2528, 1986; Biochemical and Biophysical

Res. Communications vol. 140, N° 3, pp. 874-880, 1986; Biochemical and Biophysical Res. Communications vol. 133, N° 2, pp. 554-562, 1985; Science vol. 230, pp. 1385-1388, December 20th, 1985.

Human bFGF is a polypeptide with 146 aminoacids, having the sequence shown hereunder :

5  
1 10  
Pro Ala Leu Pro Glu Asp Gly Gly Ser Gly Ala Phe Pro Pro Gly His  
20 30  
10 Phe Lys Asp Pro Lys Arg Leu Tyr Cys Lys Asn Gly Gly Phe Phe Leu  
40  
Arg Ile His Pro Asp Gly Arg Val Asp Gly Val Arg Glu Lys Ser Asp  
15 50 60  
Pro His Ile Lys Leu Gln Leu Gln Ala Glu Glu Arg Gly Val Val Ser  
70 80  
Ile Lys Gly Val Cys Ala Asn Arg Tyr Leu Ala Met Lys Glu Asp Gly  
20 90  
Arg Leu Leu Ala Ser Lys Cys Val Thr Asp Glu Cys Phe Phe Phe Glu  
100 110  
25 Arg Leu Glu Ser Asn Asn Tyr Asn Thr Tyr Arg Ser Arg Lys Tyr  
120  
Ser Trp Tyr Val Ala Leu Lys Arg Thr Gly Gln Tyr Lys Leu Gly Ser  
130 140  
30 Lys Thr Gly Pro Gly Gln Lys Ala Ile Leu Phe Leu Pro Met Ser Ala  
146  
Lys Ser

35 Bovine bFGF differs only in position 112, where threonine is substituted by serine, and in position 128 where serine is substituted by proline.

The molecule of human bFGF, as well as of bovine bFGF, can have an N-terminal extension that can contain all or part of the sequence of the following 11 aminoacids :

- 40 (i) Gly-Thr-Met-Ala-Ala-Gly-Ser-Ile-Thr-Thr-Leu, for example, in particular, the following 9 aminoacids  
(ii) Met-Ala-Ala-Gly-Ser-Ile-Thr-Thr-Leu, or the following 8 aminoacids  
(iii) Ala-Ala-Gly-Ser-Ile-Thr-Thr-Leu, or the following 7 aminoacids  
(iv) Ala-Gly-Ser-Ile-Thr-Thr-Leu.

45 The molecules of 146 aminoacids of human and bovine bFGF can also be lacking in one or more aminoacid residues at the N-terminal.

Human aFGF is a polypeptide with 140 aminoacids, having the sequence shown hereunder

50

55

1 10  
 Phe Asn Leu Pro Pro Gly Asn Tyr Lys Lys Pro Lys Leu Leu Tyr Cys  
 20 30  
 5 Ser Asn Gly Gly His Phe Leu Arg Ile Leu Pro Asp Gly Thr Val Asp  
 40  
 Gly Thr Arg Asp Arg Ser Asp Gln His Ile Gln Leu Gln Leu Ser Ala  
 10 50 60  
 Glu Ser Val Gly Glu Val Tyr Ile Lys Ser Thr Glu Thr Gly Gln Tyr  
 70 80  
 15 Leu Ala Met Asp Thr Asp Gly Leu Leu Tyr Gly Ser Gln Thr Pro Asn  
 90  
 Glu Glu Cys Leu Phe Leu Glu Arg Leu Glu Glu Asn His Tyr Asn Thr  
 100 110  
 20 Tyr Ile Ser Lys Lys His Ala Glu Lys Asn Trp Phe Val Gly Leu Lys  
 120  
 Lys Asn Gly Ser Cys Lys Arg Gly Pro Arg Thr His Tyr Gly Gln Lys  
 130 140  
 25 Ala Ile Leu Phe Leu Pro Leu Pro Val Ser Ser Asp

Bovine aFGF is also a polypeptide with 140 aminoacids, having the sequence shown hereunder and characterized by a high degree of homology with that of human aFGF,

30  
 1 10  
 Phe Asn Leu Pro Leu Gly Asn Tyr Lys Lys Pro Lys Leu Leu Tyr Cys  
 35 20 30  
 Ser Asn Gly Gly Tyr Phe Leu Arg Ile Leu Pro Asp Gly Thr Val Asp  
 40 40  
 Gly Thr Lys Asp Arg Ser Asp Gln His Ile Gln Leu Gln Leu Cys Ala  
 50 60  
 Glu Ser Ile Gly Glu Val Tyr Ile Lys Ser Thr Glu Thr Gly Gln Phe  
 70 80  
 45 Leu Ala Met Asp Thr Asp Gly Leu Leu Tyr Gly Ser Gln Thr Pro Asn  
 90  
 Glu Glu Cys Leu Phe Leu Glu Arg Leu Glu Glu Asn His Tyr Asn Thr  
 100 110  
 50 Tyr Ile Ser Lys Lys His Ala Glu Lys His Trp Phe Val Gly Leu Lys  
 120  
 Lys Asn Gly Arg Ser Lys Leu Gly Pro Arg Thr His Phe Gly Gln Lys  
 55 130 140  
 Ala Ile Leu Phe Leu Pro Leu Pro Val Ser Ser Asp

The molecules of both human and bovine aFGF can also have the same extensions and deletions at the N-terminal indicated above with reference to bFGF molecules. The fibroblast growth factors according to the invention can also be idated at the C-terminal.

5 An analogue of the aforementioned fibroblast growth factors can be, for example, according to the invention, any fragment, even in amidated form, of the entire FGF molecule, which retains its capacity to bind to the receptor.

Examples of such fragments are described in the published European patent application N° 246.753. They may be, for example, in particular, the polypeptides composed of the aminoacid sequences 93-120; 97-120; 100-120; 103-120; 103-146; 106-115; 106-118; 106-120; 106-125; 106-130; 106-135; 106-140; 106-146 and 107-110 of both human and bovine bFGF, both in free form and in amidated form.

10 An analogue of the fibroblast growth factor of the invention can be a mutein deriving from the aforementioned FGF polypeptides or their analogues, both in amidated and non-amidated form, by replacement and/or deletion of one or more aminoacids, which retains equivalent properties, in particular an equivalent capacity to bind itself to the FGF receptor. Thus, for example, the aminoacid in position 112 can be either Thr or Ser; the aminoacid in position 128 can be either Ser or Pro; the aminoacid in position 113 can be either Ala or Ser; the aminoacid in position 114 can be either Met or Trp and the aminoacid in position 115 can be either Phe or Tyr.

Mixtures of different forms of FGF, for example, of the forms referred to previously which derive from different types of extensions or deletions at the N-terminal, are also to be considered as being within the scope of this invention. The term "fibroblast growth factor" as used herein refers also to such mixtures, as well as to all the analogues indicated above.

As mentioned previously, the growth factors used according to the invention are known factors and can therefore be prepared by known methods, for example by recombinant DNA techniques, e.g. by procedures similar to those described in the published international patent applications PCT WO86/07595 and PCT W087/01728 and in the published European patent applications N° 226181, N° 237966 and N° 259953, mentioned previously.

Known techniques may also be used to obtain the FGF analogues, e.g. the fragments of FGF of the invention. For example, it is possible to use procedures similar to those described in the aforesaid published European patent application N° 246753 and in the references mentioned therein, for example by means of solid phase synthesis as described in JACS 85, pg.2149 (1963). Chemical synthesis is preferred for fragments composed of short aminoacid sequences, e.g. sequences shorter than 40 aminoacids, whereas preparation by recombinant DNA is preferred, for example, for preparing native FGF molecules or their analogues containing, e.g., more than 40 aminoacids.

35 The sulfated polysaccharide with antiviral activity component of the compositions of the invention may be, e.g., selected from the group consisting of a carrageenan, heparin, dextran sulfate, pentosan polysulfate, mannane sulfate, dermatan sulfate, heparin super-sulfated, dermatan super-sulfated and an agarose-type sulfated polysaccharide produced by marine algae belonging to the class of Rhodophyceae (red algae). The agarose-type sulfated polysaccharides produced by red algae, according to the invention (hereinafter designed as ASP) have a common backbone of the agaroid-type, composed of alternating  $\beta(1\rightarrow4)$ D-galactose and  $\alpha(1\rightarrow3)$ L-galactose repeating units. In particular, after being purified to homogeneity by anion exchange chromatography by application of an increasing sodium chloride gradient, dialysed exhaustively against distilled water, and freeze-dried, they have the following properties :

- (a) elementary analysis : 20-35% carbon, 3.2-5.5% hydrogen, less than 1% nitrogen and more than 8% sulphur, when calculated as anhydrous compound;
- 45 (b) molecular weight of up to 10000 kDa as measured by high performance size exclusion chromatography;
- (c) soluble in water, in aqueous phosphate buffers at pH 1 to 13, and in aqueous solvents containing up to 20% water-soluble alcohols, but insoluble in benzene, chloroform, ethyl ether, and in aqueous-alcoholics solutions containing more than 80% methyl- or ethyl-alcohol and 1 g/l of sodium chloride;
- 50 (d) soluble in water in the presence of barium chloride, but, after being hydrolysed for 3 hrs at 120° C in aqueous 2 M hydrochloric acid, it gives a precipitate of barium sulphate upon addition of barium chloride;
- (e) galactose, 3,6-anhydrogalactose and all their derivatives carrying one to three substituents selected from the group of sulfate hemiester, methyl ether, pyruvate (1-carboxyethylidene groups and a sugar residue like galactose or xylose, together accounts for more than 90% of the total monosaccharidic units;
- 55 (f) more than 30% of the total monosaccharidic units consists of 4-O-linked  $\alpha$ -L-galactopyranosidic residues which can carry substituents as under (e) above at positions 2, 3 and 6;
- (g) more than 40% of the total monosaccharidic units consists of 3-O-linked  $\beta$ -D-galactopyranosidic

residues which can carry substituents as under (e) above at positions 2, 4 and 6;

(h) more than 40% of the total monosaccharidic units consist of 4-0-linked  $\alpha$ -L-galactopyranosidic residues which can carry substituents as under (e) above at positions 2,3 and 6, plus 4-0-linked 3,6-anhydro- $\alpha$ -L-galactopyranosidic residues which can carry substituents as under (e) above at position 2;

(i) pyruvate (1-carboxyethylidene) groups linked as cyclic ketals bridging 0-4 and 0-6 of  $\beta$ -D-galactopyranosidic residues occur as substituents in less than 10% of the total monosaccharidic units;

(j) the molar ratio of methyl ether group substituents per monosaccharidic unit do not exceed 0.3:1;

(k) sulphate hemiester groups can be present at positions 2, 4 and 6 of the  $\beta$ -D-galactopyranosidic residues, at positions 2,3 and 6 of the  $\alpha$ -L-galactopyranosidic residues and at position 2 of the 3,6-anhydro- $\alpha$ -L-galactopyranosidic residues, and the total degree of sulfation (D.S.), that is the mean number of sulfate hemiester groups per monosaccharide unit, is always greater than 0.6;

(l) the contribution of sulfate hemiester groups, at position(s) 2 and 4 to the total degree of sulfation is always greater than 0.3.

The percentages under (a) are by weight. The percentages under (e) to (i) are molar percentages.

Preferably the ASP isolated from different sources have approximately a D.S. of  $0.9 \pm 0.1$ .

The agaroid skeleton of ASP may bear some out-of-chain galactose residues (up to 5%) as branch units, and up to 10% of the 4-0-linked  $\alpha$ -L-galactopyranose residues may be replaced by 4-0-linked  $\alpha$ -D-galactopyranose units.

Traces of xylose, which in the purified ASP does not exceed 5%, are frequently detected. If present, xylose occurs as branch units and may be eliminated by oxydation ( $\text{KIO}_4$ ), followed by reduction ( $\text{NaBH}_4$ ) and mild hydrolysis ( $\text{H}^+$ ). The presence of xylose is not considered to be a distinctive feature, as the biological properties of ASP remain substantially unaffected in the presence or absence of this component.

ASP behaves as a relatively homogeneous chemical entity but is polydisperse, with a ratio  $\overline{\text{MW}}/\overline{\text{MN}}$  usually greater than 2, and MP ranging 100 to 300 kDa.

$\overline{\text{MW}}$  means weight-average molecular weight;

$\overline{\text{MN}}$  means number-average molecular weight; and

MP means molecular weight at peak maximum.

The ASP may be isolated starting directly from red algae to produce agarose, from residues of the manufacturing of agars (aqueous extracts) or, still in appreciable amounts, from general purpose commercial agars which have not been extensively purified.

Particularly preferred sulfated polysaccharides are carrageenan, heparin, dextran sulfate, pentosan polysulfate and ASP.

The sulfated polysaccharides of the invention are known compounds or may be obtained by known methods from known compounds or sources.

The ratio between the FGF component and the sulfated polysaccharide component in the compositions of the invention may vary widely, for example in general between 1 : 100 and 100 : 1. A ratio between 20 : 1 and 1 : 20 is preferable, particularly when the sulfated polysaccharide is carrageenan.

The antiviral activity of the pharmaceutical compositions of the invention has been generally tested, e.g., *in vitro* on Herpes simplex type 1 and type 2.

The tests were generally performed by resuspending monolayers of the permissive cells by tryptic treatment, and by seeding the suspensions ( $10 \times 10^4$  cells/ml, in Minimal Essential Medium of Eagle supplemented with 5% inactivated Foetal Calf Serum) in 96 well flat bottom culture plates.

Samples of the product-compositions of the present invention in aqueous solution were distributed in two fold serial dilutions, in duplicate, into the wells added with cells and, after 15' of contact, infected with 100 TCID<sub>50</sub> of virus/well. Points in the figures represent drug combinations necessary to reduce virus induced cytopathogenicity by 50% (CPE IV50) and numbers in parenthesis are FIC indexes.

Dose-response curves for both antiviral compounds alone and in combination were set up and the concentration of compound (sulfated polysaccharide or bFGF) required to reduce the cytopathic effect to 50% (CPE ED<sub>50</sub>) of that in the control was calculated.

Data were plotted and analyzed by the isobologram method (Elion G.B. et al., J.Biol. Chem. 208, 477, 1954).

The fractional inhibitory concentration (FIC) for each pair, i.e., compound X plus compound Y, was calculated as follows :

$$\text{FIC X} = \frac{\text{CPE IC}_{50} \text{ of the compound X in the combination}}{\text{CPE IC}_{50} \text{ of compound X alone.}}$$

$$\text{FIC Y} = \frac{\text{CPE IC}_{50} \text{ of the compound Y in the combination}}{\text{CPE IC}_{50} \text{ of compound Y alone.}}$$

Combination resulting in additive antiviral ( $\text{FIC X} + \text{FIC Y} = 1$ ) are represented by straight lines (unity lines) on the isobolograms.

When the combination resulted in synergy ( $\text{FIC X} + \text{FIC Y} < 1$ ), the representational line shifts below the unity line.

When the combination resulted in antagonistic activity ( $\text{FIC X} + \text{FIC Y} > 1$ ), the line shifts above the unity line.

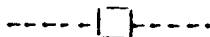
Points in the figures represent drug combinations necessary to reduce virus induced cytopathogenicity by 50% ( $\text{CPE IC}_{50}$ ) and numbers in parenthesis are FIC indexes.

The *in vitro* effect of various combinations of  $\lambda$  carrageenan and bFGF (internal code FCE 26184) against HSV-1 are reported in Figure 1.

The results obtained combining variable concentrations of  $\lambda$  carrageenan (from 1 to 0.015 mcg/ml) with constant concentrations of bFGF (100-50-25-12.5 nM) are represented by the lines



and



The antiviral effect of variable concentrations of bFGF (from 200 to 3,12 nM) with constant concentrations of carrageenan (0.5-0.25-0.125-0.06 mcg/ml) are represented by the lines



and



In both cases a synergistic effect is obtained with the best synergism being shown by a combination containing 25 nM of bFGF and carrageenan at a concentration of 0.082 mcg/ml.

The *in vitro* effect of various combinations of  $\lambda$  carrageenan and bFGF (internal code FCE 26184) against HSV-2 are reported in Figure 2.

The results obtained combining variable concentrations of  $\lambda$  carrageenan (from 0.2 to 0.003 mcg/ml) with constant concentrations of bFGF (100-50-25-12.5 nM) are represented by the lines



and



5 The antiviral effect of variable concentrations of bFGF (from 200 to 3.12 nM) with constant concentrations of  $\lambda$  carrageenan (0.1-0.05-0.025-0.0125 mcg/ml) are represented by the lines



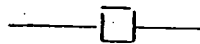
10 and



15 In both cases a synergistic effect is obtained, with the best combination being constituted by a combination containing 123.5 nM of bFGF and 0.0125 mcg/ml of  $\lambda$  carrageenan.

The *in vitro* effect of various combinations of pentosan polysulfated and bFGF (internal code FCE 26184) against HSV-1 is reported in Figure 3.

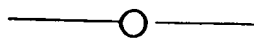
20 The results obtained combining variable concentrations of pentosan polysulfate (from 10 to 0.15 mcg/ml) with constant concentration of bFGF (100-50-25-12.5 nM) are represented by the lines



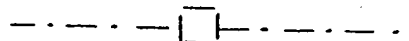
25 and



30 The antiviral effect of variable concentrations of bFGF (from 200 to 3.12 nM) with constant concentrations of pentosan polysulfate (5-2.5-1.25-0.6 mcg/ml) is represented by the lines



35 and

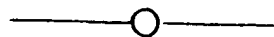


40

In both cases a synergistic effect is obtained with the best synergism being shown by a combination containing 71.4 nM of bFGF and pentosan polysulphate at a concentration of 0.6 mcg/ml.

The *in vitro* effect of various combination of dextran sulfate (M.W. 8000) and bFGF (internal code FCE 26184) against HSV-1 is reported in Fig.4.

45 The results obtained combining variable concentrations of dextran sulfate (from 10 to 0.15 mcg/ml) with constant concentrations of bFGF (100-50-25-12.5 nM), represented by the lines



50 and



55

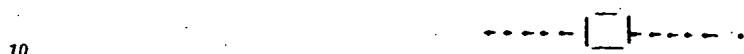
indicate that a synergistic effect is obtained. The maximum effect is reached combining 12.5 nM of bFGF and 3.9 mcg/ml of dextran sulfate. The *in vitro* effect of various combinations of the sulfated polysaccharides ASP (lot 8682/54) and bFGF against HSV-1 is reported in Fig.5.



The results obtained combining variable combinations of ASP (lot 8682/54) (from 0.8 to 0.125 mcg/ml) with constant concentrations of bFGF (100-50-25-12.5 nM) are represented by the lines



and



The antiviral effect of variable concentrations of bFGF (from 200 to 3.12 nM) with constant concentrations of ASP (lot 8682/54) (0.2-0.1-0.05-0.025) is represented by the lines



and



In both cases a synergistic effect is obtained, with the best combination being constituted by a combination containing 25-50 nM of bFGF and 0.0125-0.05 mcg/ml of ASP (lot 8682/54). The in vitro effect of various combinations of ASP (lot 8682/54) and bFGF against HSV-2 is reported in figure 6.

The results obtained combining variable concentrations of ASP (lot 8682/54) (from 0.8 to 0.0125 mcg/ml) with constant concentrations of bFGF (100-50-25-12.5 nM) are represented by the lines



and



The antiviral effect of variable concentrations of bFGF (from 200 to 3.12 nM) with constant concentrations of ASP (lot 8682/54) (0.2-0.1-0.05-0.025 mcg/ml) is represented by the lines



and



In both cases a synergistic effect is obtained, with the best effect being constituted by a combination containing 12.5-25 nM of bFGF and 0.026 - 0.047 mcg/ml of ASP (lot 8682/54).

With reference to the figures 1 to 6, the bFGF (FCE 26184) whose preparation is described in the experimental section hereinbelow, represents a human bFGF of 153-154 aminoacids, precisely an approximately 50:50 mixture of a) a 153 aminoacid molecule having the sequence of 146 aminoacids shown previously for human bFGF and a N-terminal extension of 7 aminoacids as indicated in point (iv) on page 5, and b) a 154 aminoacid molecule having the sequence of 146 aminoacids shown previously for human bFGF and a N-terminal extension of 8 aminoacids as indicated in point (iii) on page 5.

Similar results could be obtained also with other bFGF forms, e.g. the human bFGF 146 aminoacid form depicted by the sequence on page 4.

The pharmaceutical compositions of the invention may comprise one or more of the said growth factors,

one or more of the said sulfated polysaccharides, as such or as pharmaceutically acceptable salt thereof, and one or more pharmaceutical acceptable excipients.

Examples of pharmaceutically acceptable salts of the fibroblast growth factors of the invention can be the salts with pharmaceutically acceptable inorganic acids for example hydrochloric, hydrobromic, sulphuric and phosphoric acid, and salts with pharmaceutically acceptable organic acids, e.g. acetic, citric, maleic, malic, succinic, ascorbic and tartaric acid.

Examples of pharmaceutically acceptable salts of the sulfate polysaccharides of the invention can be salts with pharmaceutically acceptable inorganic bases, for example alkali metal hydroxides such as sodium or potassium hydroxide or alkaline earth metal hydroxides, such as calcium hydroxide.

The two components of the composition may be combined in any suitable way. Although it is possible to provide the combination as a two-component system, it is preferable to produce a one-component system in which both components are combined with each other in a common excipient.

The excipient may be any medium which is conventional or suitable for this purpose.

The compositions of the invention can be administered, for example, by the topical, parenteral, intravenous, intrathecal or oral route.

One particularly preferred route of administration is the topical route which is used, for example, in the treatment of skin and/or eye infections caused by HSV1 virus or of genital infections caused, e.g., by HSV2, or of respiratory infections caused by HRSV.

Compositions suitable for topical administration can be for example, creams, pastes, ointments or lotions for dermatological treatment; suppositories or pessaries for the treatment of vaginal infections; collyrium for the treatment of ocular infections; or aerosols for the treatment of infections of the respiratory system, especially, for example, for treating HRSV infections in newborn babies.

These formulations can be prepared according to known techniques; for example, creams, pastes, ointments and lotions can be obtained by mixing the active principle with conventional oleaginous or emulsifying excipients. Compositions suitable for intravenous or intrathecal administration can be, for example, sterile aqueous solutions or sterile isotonic physiological saline solutions. Compositions suitable for parenteral administration can be, for example, suspensions or solutions containing the active principle and a pharmaceutically acceptable carrier as such, for example, sterile water, olive oil, glycols, for example propylenic glycols and, if desired, an appropriate quantity of lidocaine hydrochloride.

Formulations suitable for oral administration can be, e.g., tablets or capsules coated with a gastro- and enteroresistant-layer, in which the active principle can be mixed, for example, with diluents, e.g., lactose, dextrose and the like; lubricants, e.g., silica, talcum, stearic acid and the like; binders, e.g., starch; disaggregants, e.g., alginic acid and alginates; and other excipients commonly used for this type of formulation.

In general, the pharmaceutical compositions according to the invention can be prepared with known techniques and according to procedures commonly used in the field of galenic preparations.

The beneficial dose depends upon the pathological condition to be treated, the type of formulation used, the condition of the patient and the length of the treatment. Formulations suitable for topical administration can be, for example, creams pastes, ointments, lotions, vaginal pessaries, suppositories and collyriums.

The following examples show non-restrictive methods for preparing the FGF growth factors and the analogues thereof according to the invention.

#### EXAMPLE 1

##### Preparation of b-FGF (FCE 26184)

The construction of synthetic DNA sequence for b-FGF and of the expression plasmid carrying such sequence was performed according to the procedure described in EP-A-363675. The fermentation and purification process was carried out as follows :

##### a) Fermentation process

A bacterial strain, *E.coli* type B, from the Institute Pasteur collection, was transformed with a plasmid carrying both the human gene for b-FGF and the gene for tetracycline resistance. This transformed strain was used for the production of recombinant non-glycosylated h-b-FGF (human b-FGF). A Master Cell Bank (15 freeze-dried vials) and a Working Cell Bank (W.C.B.) (70 vials stored in liquid nitrogen at -190° C) of this strain were prepared. The content of one vial of W.C.B. was used as the inoculum for the

fermentation phase.

The fermentation process was carried out in 10 l fermentors filled with 4 l of culture medium.

Tetracycline hydrochloride was added to the medium in order to maintain the conditions of strain selection.

5 After 20 hours of growth at 37° C the final biomass was 42±2 g/l dry weight, and the production of b-FGF was 2500±500 mg/l as measured by comparative gel electrophoresis.

Enrichment in pure oxygen was required during the fermentation phase in order to allow a large bacterial growth.

#### 10 (b) Initial purification

The cells (microorganisms) were separated from the total fermentation broth by centrifugation. The resulting pellet was resuspended in a sodium phosphate buffer containing sodium chloride. A minimum of 3 passages through a high pressure homogenizer were necessary for efficient cell breakage. The resulting  
15 cell lysate was clarified by centrifugation and the supernatant was collected for further processing.

#### (c) Purification

The clarified supernatant was loaded on a column of Sepharose (Trade Mark) S Fast Flow (cation  
20 exchanger) and the product was eluted from this column using a gradient of increasing sodium chloride concentrations in a phosphate buffer (Trade Mark). The product was further purified on a column of Heparin Sepharose 6 B by eluting with a gradient on increasing sodium chloride concentration in a phosphate buffer. Finally a buffer exchange was made on a Sephadex (Trade Mark) G25 resin to obtain the product in the  
25 bulk product buffer (sodium phosphate -EDTA).

#### (d) Column sanitization

Sepharose S Fast Flow and Sephadex G25 columns were sanitized by washing with sodium hydroxide solutions. Heparin Sepharose was washed alternatively with solutions at pH = 8.5 and pH = 5.5 containing  
30 3M sodium chloride.

### EXAMPLE 2

#### Preparation of b-FGF fragments.

35 The synthesis of fragment 93-120 of bFGF with the formula :

H-Phe-Phe-Phe-Glu-Arg-Leu-Glu-Ser-Asn-Asn-Tyr-Asn-Thr-Tyr-Arg-Ser-Arg-Lys-Tyr-Ser-Ser-Trp-Tyr-Val-Ala-Leu-Lys-Arg-NH<sub>2</sub> was carried out in consecutive stages using a peptide synthesizer and MBHA resin. The bond to the resin was obtained via BOC-Val according to the procedures described in the USA patent  
40 N° 4292313. After bonding to the resin the amino protective group was removed for treatment with trifluoroacetic acid at 0° C. After deprotection and subsequent neutralization, the peptide chain was constructed step by step on the resin following the procedure described in the USA patent N° 3,904,594.

A similar method can be used to prepare the following peptides :

1) fragment 97-120 of bFGF with the formula :

H-Arg-Leu-Glu-Ser-Asn-Asn-Tyr-Asn-Thr-Tyr-Arg-Ser-Arg-Lys-  
-Tyr-Ser-Ser-Trp-Tyr-Val-Ala-Leu-Lys-Arg-NH<sub>2</sub> ;

50 2) fragment 100-120 of bFGF with the formula :

H-Ser-Asn-Asn-Tyr-Asn-Thr-Tyr-Tyr-Arg-Ser-Arg-Lys-Tyr-Ser-  
55 -Ser-Trp-Tyr-Val-Ala-Leu-Lys-Arg-NH<sub>2</sub> ;

3) fragment 103-120 with the formula:

H-Tyr-Asn-Thr-Tyr-Arg-Ser-Arg-Lys-Tyr-Ser-Ser-Trp-Tyr-Val-  
-Ala-Leu-Lys-Arg-NH<sub>2</sub>;

4) fragment 103-106 with the formula :

H-Tyr-Asn-Thr-Tyr-Arg-Ser-Arg-Lys-Tyr-Ser-Ser-Trp-Tyr-Val-  
-Ala-Leu-Lys-Arg-Thr-Gly-Gln-Tyr-Lys-Leu-Gly-Pro-Lys-Thr-  
-Gly-Pro-Gly-Gln-Lys-Ala-Ile-Leu-Phe-Leu-Pro-Met-Ser-Ala-  
-Lys-Ser-NH<sub>2</sub>;

5) fragment 106-115 with the formula : H-Tyr-Arg-Ser-Arg-Lys-Tyr-Ser-Ser-Trp-Tyr-NH<sub>2</sub>;

6) fragment 106-118 with the formula:

H-Tyr-Arg-Ser-Arg-Lys-Tyr-Ser-Ser-Trp-Tyr-Val-Ala-Leu-  
-NH<sub>2</sub>;

7) fragment 106-120 with the formula :

H-Tyr-Arg-Ser-Arg-Lys-Tyr-Ser-Ser-Trp-Tyr-Val-Ala-Leu-Lys-  
-Arg-NH<sub>2</sub>;

8) amidated fragment 106-125 of bFGF;

9) amidated fragment 106-130 of bFGF;

10) amidated fragment 106-135 of bFGF;

11) amidated fragment 106-140 of bFGF;

12) amidated fragment 106-146 of bFGF;

13) amidated fragment 107-110 of bFGF.

### EXAMPLE 3

#### Extraction and Purification of ASP (lot 8682/54)

454 g of Bacto-Agar (TM) Difco were suspended in 6 l of aqueous 0.5 M NaCl, containing 2 mM sodium azide, and vigorously stirred for 2 h at room temperature. The aqueous extract (4400 ml) obtained by filtering through glass wool, was added of 37 ml of 5 M NaCl, 24 ml of 2 M sodium sulphate, and 330 ml of a 6% (w/v) aqueous solution of cetyltrimethyl -ammonium bromide (CTAB), under stirring, while slightly warmed (40° C) for 30 min. and allowed to aggregate while standing for at least 2 h at room temperature. The presence of 0.5 M NaCl prevented pectins and low charge density sulphated polysaccharides (D.S. <0.3) from precipitating.

The precipitate was collected by brief centrifugation and dissolved in 640 ml of 4 M NaCl while stirring at 40° C overnight. The residual agarose and insoluble impurities were centrifuged off.

Sodium sulphate (14 ml, 2M) CTAB (46 ml, 6%) and 2040 ml of water were sequentially and slowly added to the clear supernatant (700 ml, from re-dissolution in 4M NaCl) with good mixing, lowering the sodium chloride concentration down to 1M, and promoting an homogeneous precipitation. After warming (40° C, 30 min.) with stirring and standing (≥ 2 h) at room temperature, the precipitate, which centrifuges upward, was collected and re-dissolved in 300 ml of 4 M NaCl (40° C, with stirring, overnight).

Methanol (1685 ml) was added slowly, with adequate stirring, to the clear solution (315 ml) to precipitate sulphated polysaccharides as their sodium salts, leaving all CTAB and most NaCl in the supernatant (2000 ml, 84% MeOH).

Stirring was maintained for at least 2 h, when ion exchange proceeded to completion.

The precipitate was collected by filtration, dissolved in 150 ml of water (tot. vol.180 ml), completely clarified by filtration (0.45 µm) and precipitated again in 84% MeOH (by addition of 1000 ml MeOH) to

remove all NaCl. Final washes with 95% MeOH (350 ml twice) and 100% MeOH (300 ml) and drying afforded the purified sodium salts of sulphated polysaccharides having a D.S.  $\geq$  0.6 in 1.0% yield (4.4 g, lot 8682/54, D.S. = 0.85).

## 5 Claims

1. A synergistic pharmaceutical composition having anti-viral activity which comprises a fibroblast growth factor, a sulfated polysaccharide with antiviral activity and any acceptable pharmaceutical excipient or excipients for use in the prevention or treatment of viral infections caused by enveloped viruses.
2. A pharmaceutical composition according to claim 1 wherein the fibroblast growth factor is basic fibroblast growth factor (b-FGF), or an analogue thereof.
3. A pharmaceutical composition according to claim 2 wherein the analogue is a fragment of the entire molecule.
4. A pharmaceutical composition according to claim 1 wherein the sulfated polysaccharide with antiviral activity is selected from the group consisting of a carrageenan, heparin, dextran sulfate, pentosan polysulfate, mannan sulfate, dermatan sulfate, heparin super-sulfated, dermatan supersulfated and agarose-type sulfated polysaccharides produced by marine algae belonging to the class of Rhodophyceae (ASP).
5. A pharmaceutical composition according to claim 4 wherein the sulfated polysaccharide is carragenan, heparin, dextran sulfate, pentosan polysulfate and an agarose-type sulfated polysaccharide produced by marine algae belonging to the class of Rhodophyceae (ASP).
6. A pharmaceutical composition according to claim 1 wherein the virus is an herpes virus type  $\alpha$ ,  $\beta$  or  $\gamma$ ; an orthomyxovirus or paramyxovirus; a tropical virus or a retrovirus.
7. A pharmaceutical composition according to claim 6 wherein the herpes virus type  $\alpha$  is herpes simplex virus (HSV) or herpes varicella/zoster; the herpes virus type  $\beta$  or  $\gamma$  is a cytomegalovirus; the orthomyxovirus is an influenza virus; the paramyxovirus is the human respiratory syncytial virus (HRSV); the tropical virus is the Semliki Forest virus (SFV); the retrovirus is the Human Immunodeficiency virus (HIV) or the Moloney Sarcoma virus (MSV).
8. A pharmaceutical composition according to claim 7 wherein the herpes simplex virus is the virus HSV-1 or HSV-2.
9. A process for preparing a pharmaceutical composition according to claim 1 which process comprises the step of combining a fibroblast growth factor and a sulfated polysaccharide in a pharmaceutical acceptable excipient or excipients.
10. Use of a synergistic composition according to anyone of the preceding claims 1 to 8 in the preparation of a medicament useful in the prevention or treatment of viral infections caused by enveloped viruses.
11. A pharmaceutical composition comprising a fibroblast growth factor, a sulfated polysaccharide and an acceptable pharmaceutical excipient or excipients.
12. The use of synergistic pharmaceutical composition comprising a fibroblast growth factor and a sulfated polysaccharide with antiviral activity for the manufacture of a medicament for the prevention or treatment of viral infections caused by enveloped viruses.

## Claims for the following Contracting State : ES

1. A process for preparing a synergistic pharmaceutical composition having antiviral activity which comprises a fibroblast growth factor, a sulfated polysaccharide with antiviral activity and any acceptable pharmaceutical excipient or excipients, which process comprises the step of combining a fibroblast growth factor and a sulfated polysaccharide in a pharmaceutical acceptable excipient or excipients.

2. A process according to claim 1 wherein the fibroblast growth factor is basic fibroblast growth factor (b-FGF), or an analogue thereof.
3. A process according to claim 2 wherein the analogue is a fragment of the entire molecule.
4. A process according to claim 1 wherein the sulfated polysaccharide with antiviral activity is selected from the group consisting of a carrageenan, heparin, dextran sulfate, pentosan polysulfate, mannan sulfate, dermatan sulfate, heparin super-sulfated, dermatan supersulfated and and agarose-type sulfated polysaccharides produced by marine algae belonging to the class of Rhodophyceae (ASP).
5. A process according to claim 4 wherein the sulfated polysaccharide is carragenan, heparin, dextran sulfate, pentosan polysulfate and an agarose-type sulfated polysaccharide produced by marine algae belonging to the class of Rhodophyceae (ASP).
6. A process according to claim 1 wherein the virus is an herpes virus type  $\alpha$ ,  $\beta$  or  $\gamma$ ; an orthomyxovirus or paramyxovirus; a tropical virus or a retrovirus.
7. A process according to claim 6 wherein the herpes virus type  $\alpha$  is herpes simplex virus (HSV) or herpes varicella/zoster; the herpes virus type  $\beta$  or  $\gamma$  is a cytomegalovirus; the orthomyxovirus is an influenza virus; the paramyxovirus is the human respiratory syncytial virus (HRSV); the tropical virus is the Semliki Forest virus (SFV); the retrovirus is the Human Immunodeficiency virus (HIV) or the Moloney Sarcoma virus (MSV).
8. A process according to claim 7 wherein the herpes simplex virus is the virus HSV-1 or HSV-2.
9. Use of a synergistic composition obtainable by a process according to anyone of the preceding claims 1 to 8 in the preparation of a medicament useful in the prevention or treatment of viral infections caused by enveloped viruses.

Fig.1

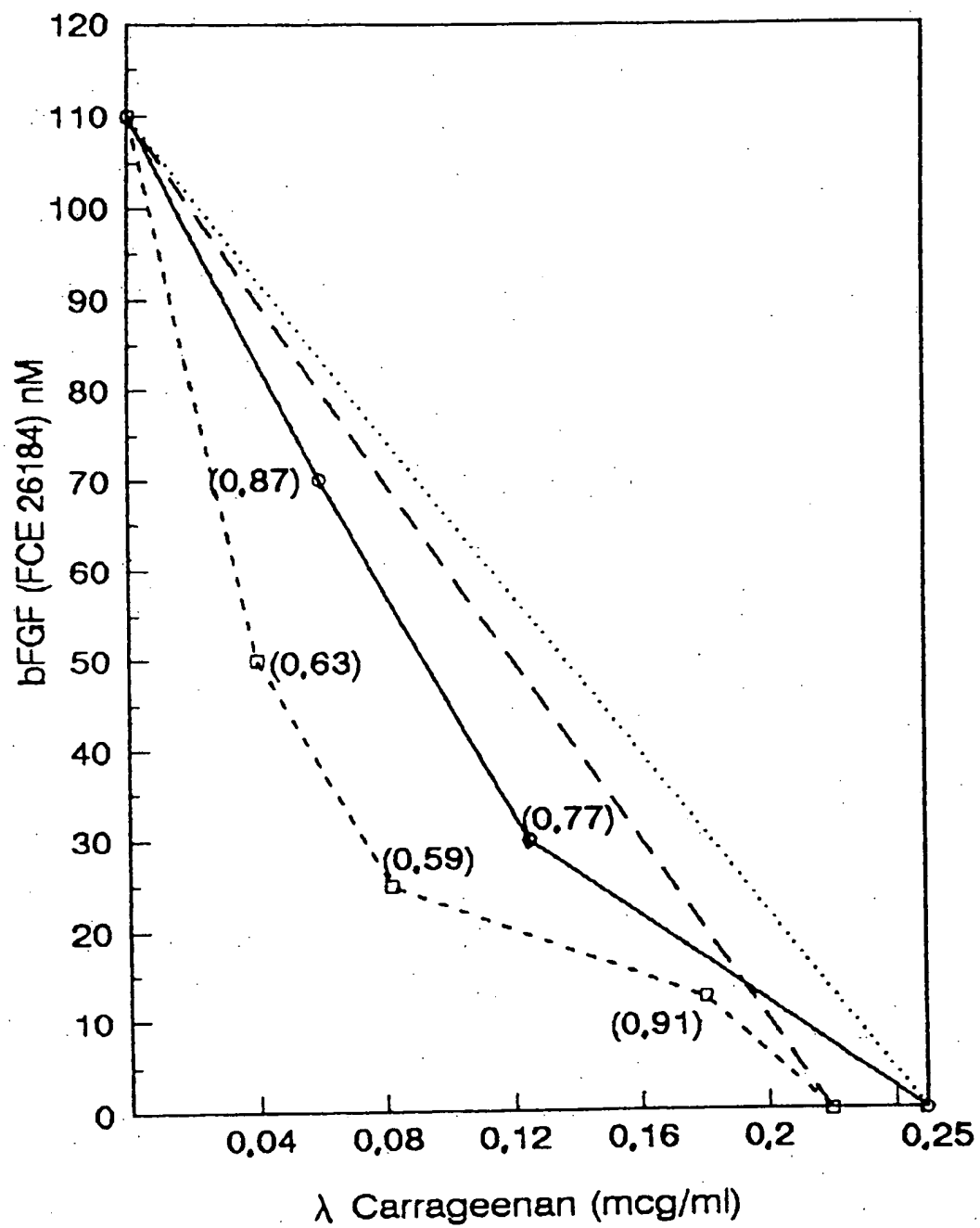


Fig. 2

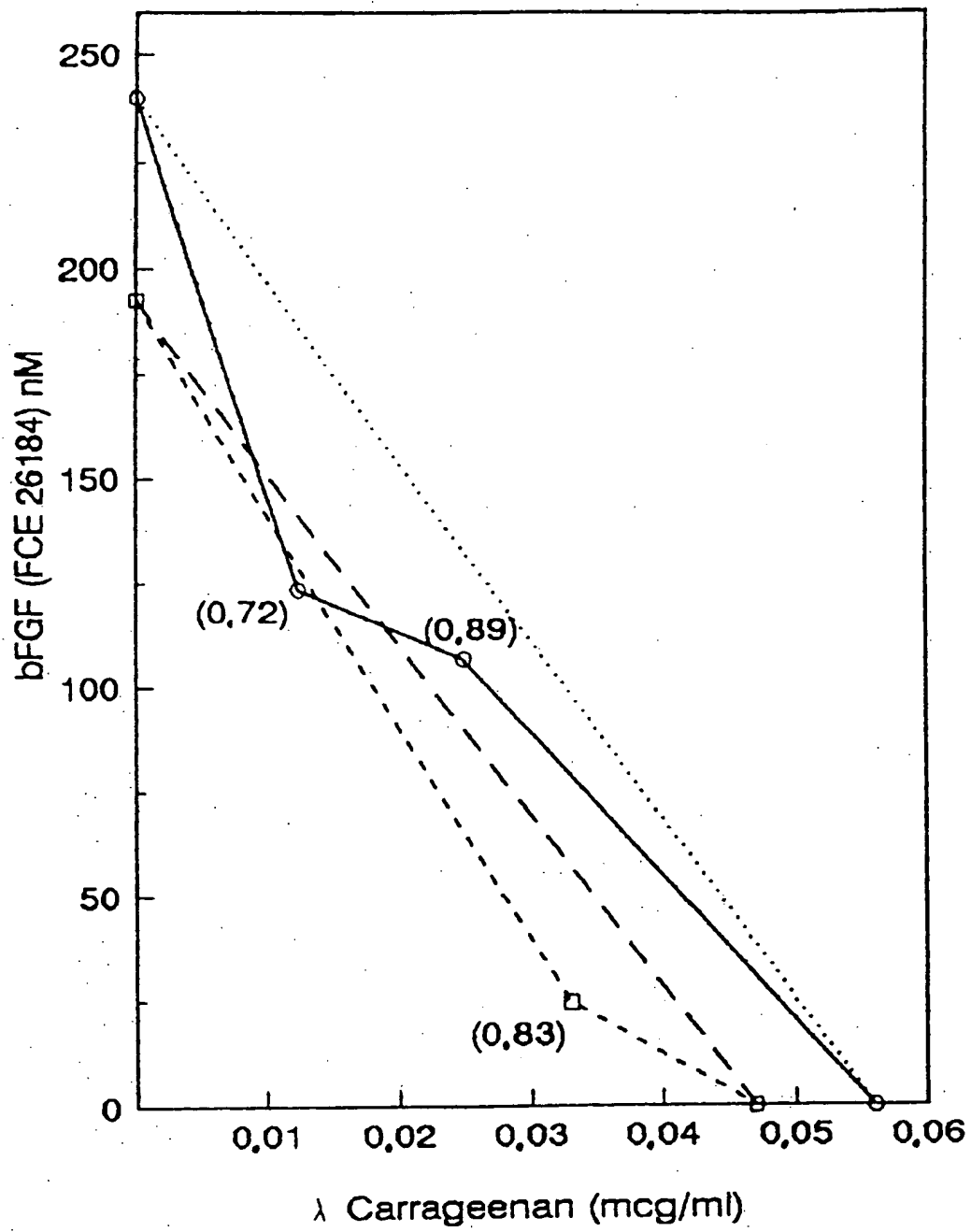




Fig. 3

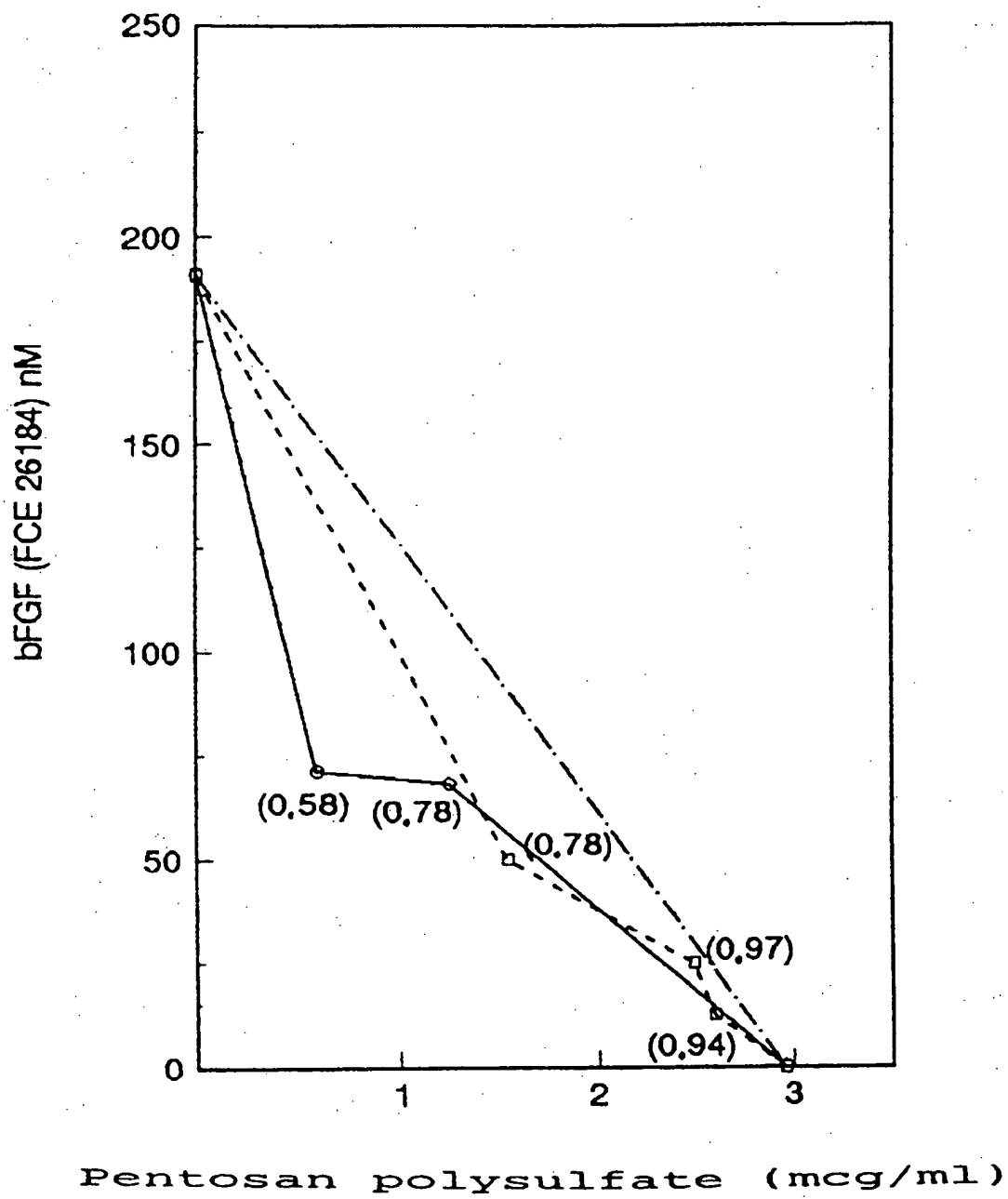


Fig. 4

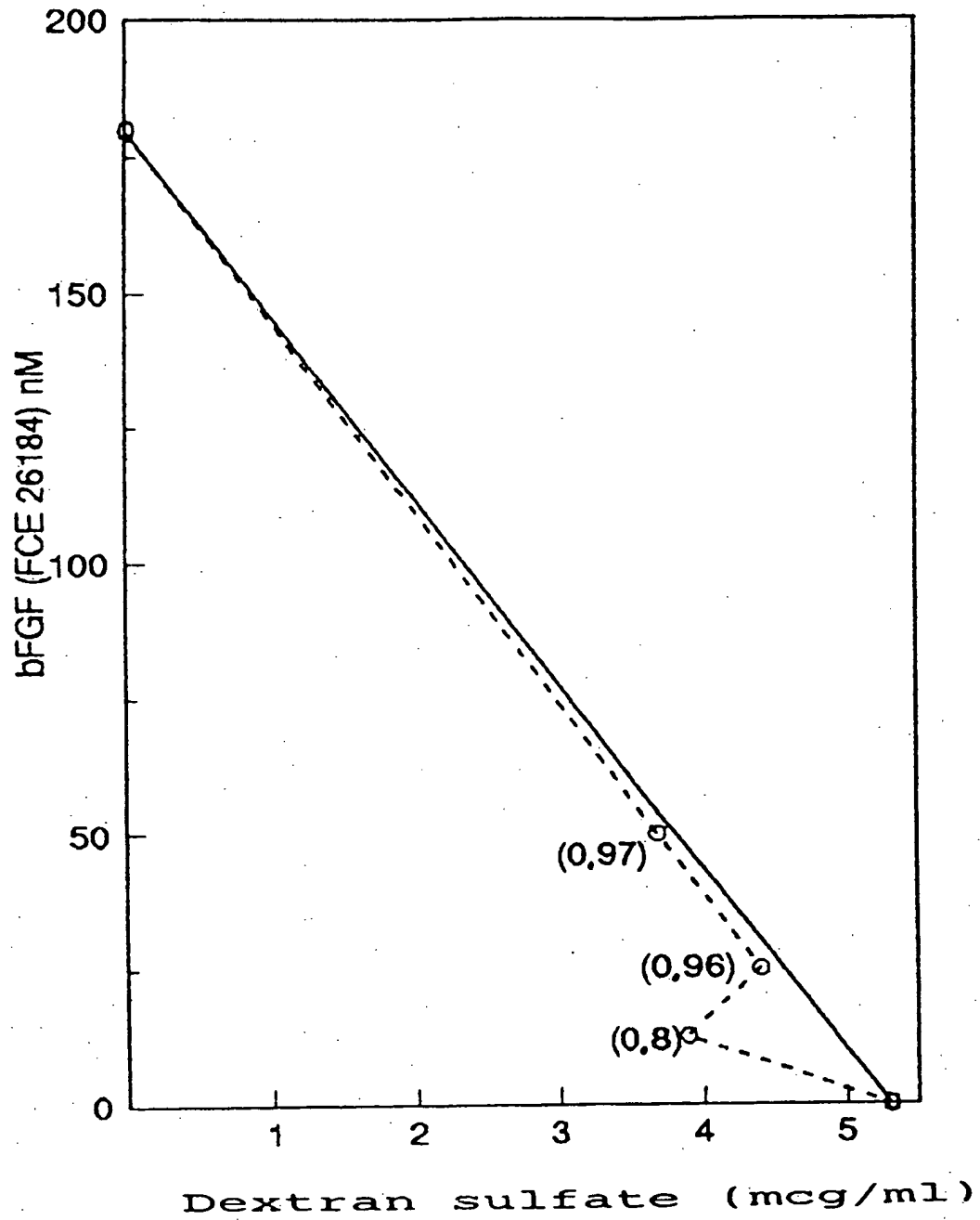


Fig. 5

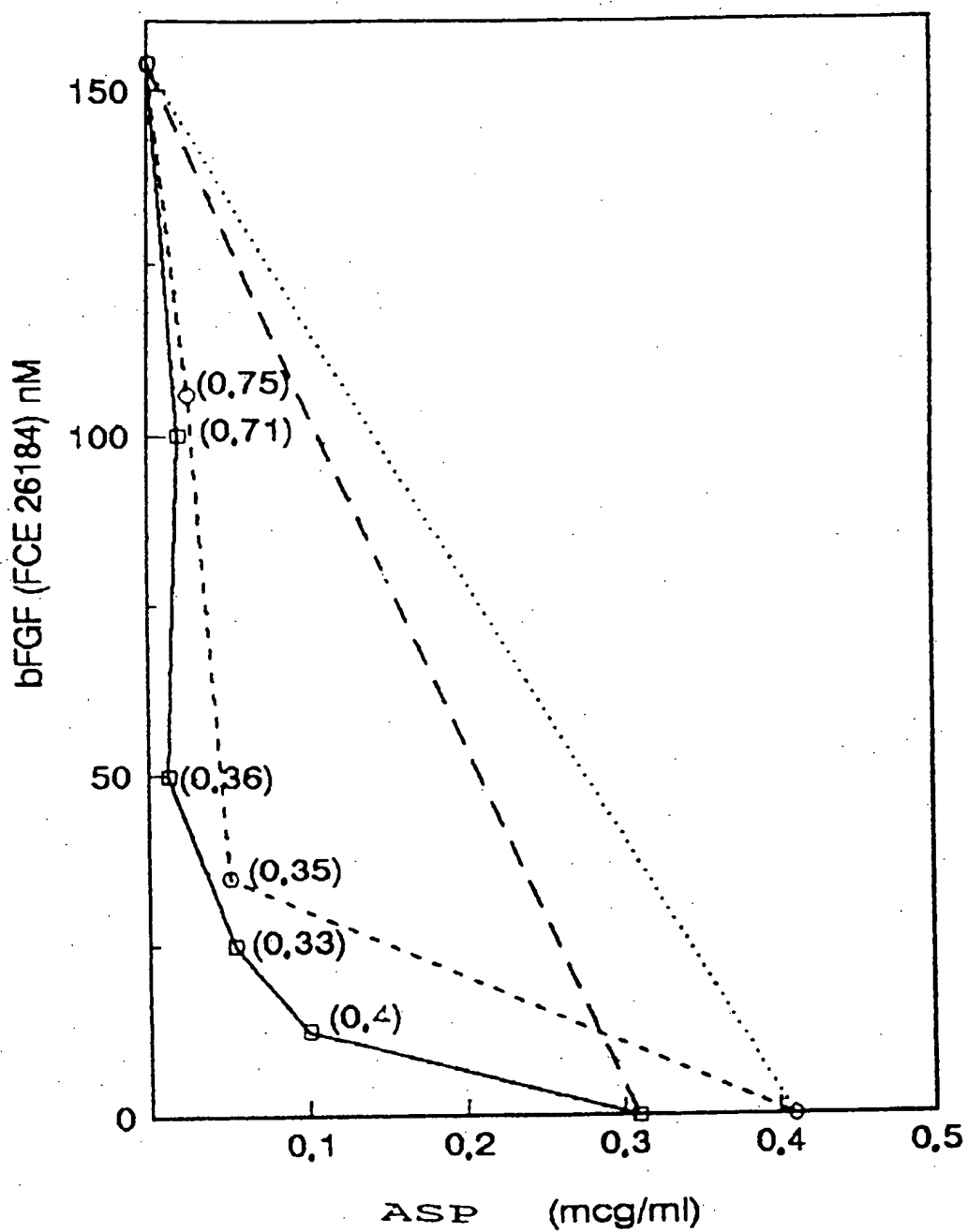
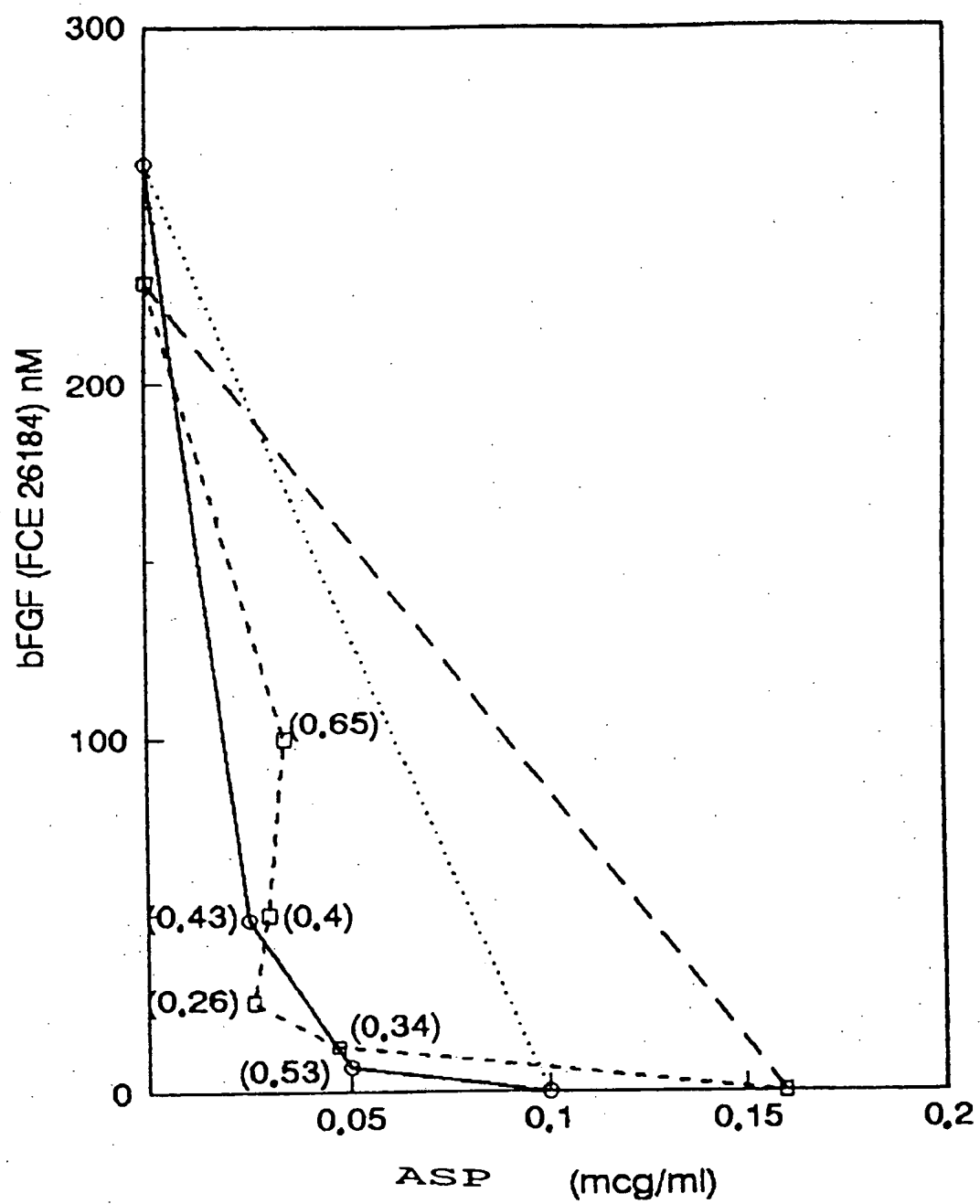


Fig. 6



(19)



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(54) Synergistic composition comprising a fibroblast growth factor and a sulfated polysaccharide, for use as antiviral agent.

(57) A pharmaceutical composition is provided for use in the prevention or treatment of viral infections caused by enveloped viruses. The composition comprises a fibroblast growth factor, a sulfated polysaccharide with antiviral activity, and one or more pharmaceutically acceptable carriers.

The fibroblast growth factor may be a basic fibroblast growth factor or an analogue thereof, and the polysaccharide may be a carrageenan, heparin, dextran sulfate, pentosan polysulfate or a sulfated polysaccharides produced by marine algae belonging to the class of Rhodophyceae.

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## EUROPEAN SEARCH REPORT

Application Number

EP 92 10 1541  
Page 1

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	EP-A-O 345 660 (TAKEDA CHEMICAL INDUSTRIES) 13 December 1989 * the whole document * ---	1-9,11	A61K37/02 //(A61K37/02 31:725)
X	EP-A-O 251 806 (MERCK & CO. INC.) 7 January 1988 * the whole document * ---	1,4-9,11	
A	EP-A-O 000 133 (CIBA-GEIGY AG) 10 January 1979 * the whole document * ---	1-12	
A	PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF USA. vol. 87, no. 18, September 1990, WASHINGTON US pages 6985 - 6989 KIEFER, M.C. ET AL 'Ligand-affinity cloning and structure of a cell surface heparan sulfate proteoglycan that binds basic fibroblast growth factor' * the whole document * ---	1-12	
A,D	THE LANCET vol. 1, no. 8546, 13 June 1987, LONDON page 1379 UENO, R. ET AL 'Dextran sulphate, a potent anti-HIV agent in vitro having synergism with zidovudine' * the whole document * --- -/--	1-12	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 03 MARCH 1993	Examiner FERNANDEZ Y BRA F.
<b>CATEGORY OF CITED DOCUMENTS</b>			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- A : member of the same patent family, corresponding document	



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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A, D	SCIENCE vol. 248, 15 June 1990, LANCASTER, PA US pages 1410 - 1413 KANER, R.J. ET AL 'Fibroblast growth factor receptor is a portal of cellular entry for herpes simplex virus type 1' * the whole document *	1-12	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 03 MARCH 1993	Examiner FERNANDEZ Y BRA F.
<b>CATEGORY OF CITED DOCUMENTS</b>			
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